

What is the part devoted to the micro-organisms in the nutrient fluxes within forested ecosystems ?

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Summary :

In forest ecosystems, the communities of microorganisms develop mainly in the soil organic layers where they control to some extent the nutrient cycling. However, in the « Haute Ardenne » country (Belgium) the forest grows on acidic soils and the litter decomposition proceeds slowly. Consequently, it is supposed that microbial activities are not the only process involved in the nutrient recycling from the organic layers. Batches of pluviometers and lysimeters were set in beech and spruce forests. The nutrient budgets were drawn up monthly for throughfall rain and seepage water below the humus layer. A computation of the results by principal component analysis allows to discriminate three main processes in the nutrient recycling from organic layers : soluble carbon production, ion exchange and solubilization, nitrate immobilization and release. The relative importance of these processes depends on the type of nutrient and forest.

Key words : acidic soils, decomposition, exchange, nitrification.

I. Introduction

Generally, it is stated that in forested ecosystems, the communities of microorganisms develop mainly in the soil organic layers and by this way, control to some extent the nutrient cycling (AUSMUS *et al.*, 1976). Moreover, this rule is rather more complicated. So, in the « Haute Ardenne » district, the forest soils are constituted by brown earth derived from pleistocenic loess loam. The main features of these soils are summarized in Table I : the soils are acidic, the humus forms are moder or dysmoder and the base saturation is low. Therefore, the litter decomposition proceeds slowly : 20 to 50 percents of weight loss in three years (PARMENTIER & REMACLE, 1981). Consequently, it can be questioned about the role of microorganisms in nutrient fluxes within these soils, especially as other, non-biological processes can be involved in the nutrient recycling from the organic layers (WIKLANDER, 1967).

TABLE I

Characteristic soil parameters.

pH (H ₂ O)	C/N	Base saturation %	Texture %
3.7	26	5	clay 30
to	to	to	silt 55
4.3	16	15	sand 15

II. Materials and methods

Batches of pluviometers and lysimeters containing the organic layers (L, F and H) were set up in beech and spruce stands. The nutrient budgets as it concerns throughfall rain and the seepage water below the humus layer were followed monthly over a two year period. Hydrogen, calcium, magnesium, sodium, potassium, iron, phosphorus, ammonia, nitrate, sulfate and total organic carbon were considered. In order to reveal the different processes involved in the nutrient recycling from the organic layers, principal component analysis has been applied to the results.

III. Results and discussion

The results of the principal component analysis are shown in Table II. Three components are evidenced by the analysis. They explain 71 and 74 % of variance respectively for the beech and the spruce analysis. These three components are supposed to represent important processes which govern the nutrient release from the organic layers and the nature of each process can be found with the help of the variables closely associated with each component. These variables can be either inputs, like the amounts of water or nutrients monthly added to the organic layers by throughfall or outputs, like the amounts of nutrients monthly leached from the organic layers.

TABLE II.

Principal component analysis applied to the nutrient balances of the beech and the spruce organic layers (in : additions by throughfall; out : leached amounts from organic layers).

	Component	Most correlated variables with the component	Variance explained by the component (%)
Beech	I	C_{out}	52
	II	Rainfall, H^+_{in} , H^+_{out} , $SO_4^{2-}_{out}$	10
	III	$NO_3^-_{in}$, $NO_3^-_{out}$	9
Spruce	I	Rainfall, H^+_{in} , H^+_{out} , $SO_4^{2-}_{out}$	55
	II	C_{out}	10
	III	$NO_3^-_{in}$, $NO_3^-_{out}$	9

1. Soluble carbon compound production

The leached amounts of carbon are closely correlated with one component : component I in the beech analysis and component II in the spruce analysis. This component can be considered as to represent the efficiency of microorganisms to produce soluble carbon compounds during the year (BILLES *et al.*, 1971). In the beech case, the percentage of variance explained by this component is 52 while it only reaches 10 in the spruce case.

2. Ion exchange and solubilization

Water and hydrogen amounts added by throughfall and hydrogen leached amounts are closely correlated with another component : component II in the beech analysis and component I in the spruce analysis. This component can be considered as to represent exchange and solubilization within the organic layers (CHRISTOPHERSEN & SEIP, 1980; TYLER, 1981). This component accounts for 55 % of variance in the spruce case, while it only reaches 10 % of variance in the beech case.

3. Nitrate immobilization and release

In both cases, the last component is represented by the monthly added and leached amounts of nitrates. The meaning of this third process can be inferred from a further examination of the results. Fig. 1 represents the relation between the leached amounts of carbon and the output-input ratio of nitrates on a yearly basis, the input of nitrate being the nitrates supplied yearly by throughfall rain. An output-input ratio greater than one means that nitrates are produced within the organic layers, because the nitrates input by litterfall is negligible. The results have been collected in different beech and spruce stands which differ mainly by their organic layer thickness. So, either for the beech or the spruce, stand 1 has much thicker organic horizons than stand 2.

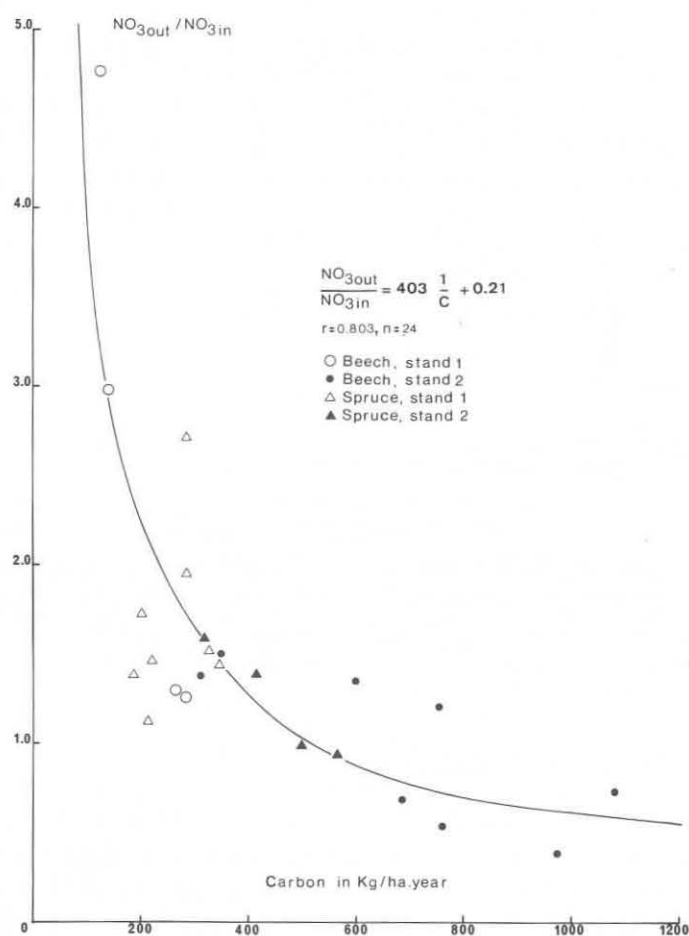


Figure 1 Nitrate output-input ratio as a function of soluble carbon leachings for the organic layers of the beech and the spruce stands (in : amounts supplied by throughfall; out : leached amounts).

So, it appears that the nitrate production within the organic layers decreases with increasing soluble carbon production. Such a relation can be explained by putting forward three hypotheses :

1. a competition between decomposers and nitrifiers for oxygen (REDDY, 1982);
2. an utilisation of nitrates as an energy source by the decomposers (BÅÅTH *et al.*, 1978);
3. and an allelopathic inhibition of nitrification by the organic compounds produced by organic matter mineralization (RICE, 1979).

It is clear that these three explanations are linked to microbial activities.

Furthermore, this kind of relation can be exemplified by data given in Fig. 2. This figure compares the inputs and outputs of two lysimeters placed in the same beech stand. The two lysimeters exhibit a different behaviour with respect to the leaching of soluble carbon and to the ammonia and nitrate output-input ratios. So, one lysimeter exhibits a higher soluble carbon compound production than the other one and consequently, nitrogen is mainly released as nitrate nitrogen from this lysimeter. In addition, the two graphs represent the nitrate production in relation with the carbon concentrations in the leaching solution during the year. In one lysimeter, since the carbon concentrations remain always low, the nitrates are released throughout the year. In the other one, nitrification only occurs during a period of low soluble carbon concentration. Moreover, in this lysimeter, some nitrate immobilization seems to be effective during periods of high soluble carbon productions.

IV. Conclusion

The principal component analysis applied to the nutrient balances of organic layers of beech and spruce stands revealed the existence of three processes which govern the nutrient release from these layers. Among these processes, two of them — soluble carbon compound production and nitrate immobilization and release — can be considered as depending on microbial activities.

Another evidenced process appears to reflect physico-chemical reactions like exchange and solubilization. In the spruce layers, the physico-chemical processes seem to predominate, while in the beech layers microbial activities are the most important process. Furthermore, either in the beech or in the spruce layers, there is a connection between the two microbial processes, in so far as we have shown that soluble organic compound production influences ammonia and nitrate releases. For example, in acidic conditions, organic layers which yearly release 800 kg of soluble carbon per hectare can immobilize 30 % of the nitrates added to the forest by throughfall. On the contrary, organic layers which yearly release 200 kg of soluble carbon per hectare, can increase two times the quantity of nitrates added to the mineral soil by throughfall.

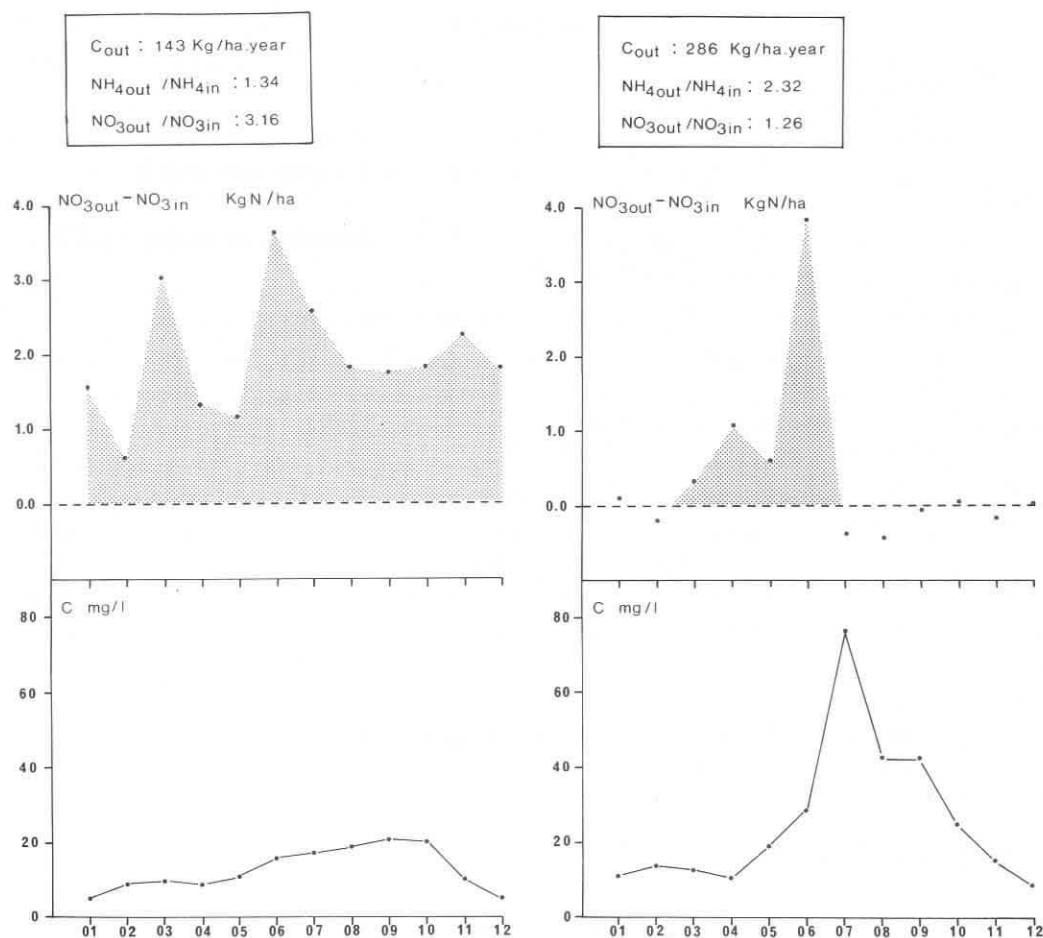


Figure 2 Evolution of the nitrate and soluble carbon production and leaching for two lysimeters placed in the same beech stand (in : amounts supplied to the organic layers by throughfall; out : amounts leached from the organic layers).

This phenomenon does not only govern the nitrogen availability for trees but, as shown by the principal component analysis, also influences the whole recycling of nutrients from the organic layers.

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